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LOW-TEMPERATURE COVERING ENAMELS FOR STEEL AND ALUMINUM

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The possibility of obtaining for steel white covering enamel with melting temperature 1000 – 1100°C and firing temperature 750 – 780°C and for aluminum white enamel with melting temperature 900 – 950°C and firing temperature 530 – 560°C is investigated. The physical and technological characteristics of the frits melted are measured and the temperature – time firing regimes with the enamel deposited in the form of slip are determined. It is established that introducing modifier oxides and glass-forming oxides makes it possible to lower the melting temperature by 15 – 20% and the enamel firing temperature by 20 – 30°C without introducing new components into the enamel composition.

Coating enamels with melting temperature 1200 – 1300°C and firing temperature interval 840 – 869°C are currently used for enameling steel articles. Enamels with lower melting and firing temperatures can lower costs substantially.

A literature search led to ways to lower the temperature characteristics of enamels. The following enamel compositions were chosen for investigation:

alkali-earth oxides ($Na_2O : K_2O : Li_2O$) were introduced in the ratio 3 : 2 : 1, which corresponds to a combined polyalkali effect, were introduced into enamels Nos. 1 and 4 to facilitate melting;

aside from alkali-earth oxides, glass-forming oxides ($SiO_2 : B_2O_3$) were introduced into enamels Nos. 2 and 5 in the ratio 2 : 1 to obtain a chemically more stable enamel;

the ratio $B_2O_3 : P_2O_3$ in the enamels Nos. 2 and 6 is 3 : 1, which will make it possible to make the glass network even stronger and to improve the operating properties of the enamel without raising its melting temperature [1].

In the present work we study the problem of obtaining white titanium enamel with melting temperature 1000 – 1100°C and firing temperature 680 – 700°C for steel and white enamel with melting temperature 900 – 950°C and firing temperature 560 – 600°C for aluminum.

The enamel frits were melted in a periodic-operation Silit furnace at temperature (1000 – 1100) ± 10°C. The total melting time was 3.5 – 4 h. The meltings performed showed that borosilicate titanium enamels with compositions Nos. 4 and 6 were completely melted at 900 – 1000°C. Gas release was moderate. The fusion process for these compositions was identical to the fusion of ordinary frit.

The CLTE was investigated with a quartz dilatometer. The average values of the CLTE of enamels at temperatures 200 – 500°C were (10^{-7}°C): composition No. 1) 117.36; No. 2) 118.55; No. 3) 115.70; No. 4) 158.68; No. 5) 274.21; No. 6) 183.30. The CLTE of the frits obtained falls within the range allowed by GOST 24405–80.

TABLE 1.

Composition	Temperature, °C	Viscosity, Pa · sec	log η	Viscous flow activation energy, kJ/mole
1	580	298×10^7	9.47	278
	600	114×10^7	9.06	
	620	621×10^6	8.79	
2	540	106×10^7	9.03	351
	560	111×10^6	8.05	
	580	556×10^5	7.75	
3	540	154×10^7	9.19	337
	560	398×10^6	8.40	
	580	957×10^5	7.98	
4	500	89×10^7	8.95	112
	520	39×10^6	7.60	
	540	23×10^6	7.40	
5	540	21×10^8	9.31	132
	560	22×10^7	8.34	
	580	71×10^6	7.85	
6	440	11×10^8	9.04	118
	460	11×10^7	8.05	
	480	31×10^6	7.51	

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TABLE 2.

Composition	Firing temperature, °C	Surface tension, mN/m	Wetting angle, deg	Adhesion energy, kJ/m^2	Onset temperature, °C		Water resistance, %	Alkali resistance, %	Acid resistance, %
					vitrification	melting			
1	800	124	97	49	655	762	99.6	93.9	88.8
2	785	118	94	111	510	736	97.2	89.1	83.5
3	760	179	119	95	530	735	98.9	95.8	89.4
4	530	71	104	53	300	678	94.7	83.2	79.8
5	420	68	85	74	312	443	93.1	81.5	77.2
6	510	75	85	80	280	442	94.5	83.1	79.9

The covering characteristics of frit are very important for obtaining a high-quality enamel coating. They are judged according to the surface tension, adhesion energy, viscosity, and spreadability of enamel on the surface of prime enamel. The results of the measurements, presented in Table 1, show that the viscosity of frits determined by pressing an indentor are close.

The surface tension of the experimental melts, determined by the reposing drop method, lies within the range specified by GOST 24405–80.

Differential thermal analysis established (Table 2) than the experimental frits have lower melting and vitrification onset temperatures than the enamels which are currently in use.

The resistances to water, acid, and alkali determined by the method of GOST 27180–86 are quite high for all compositions.

The temperature – time regimes of firing were investigated using as the metal 0.1 mm thick and 50 × 100 mm 08kp steel and AK2 aluminum plates. Slip with the composition 100 mass parts of frit, 5 mass parts of clay, and 35 mass parts of water was deposited on a steel plate coated with a layer of ÉSP-117 prime enamel and on aluminum by the pouring method.

The samples were fired in a muffle furnace for 3 – 5 min. An even shiny coating was obtained at these temperatures for steel using composition No. 3 and for aluminum using composition No. 6.

In summary, the introduction of the modifying oxides Na_2O, K_2O, and Li_2O in the ratio 3 : 2 : 1, vitrifying oxides B_2O_3 and P_2O_5 in the ratio 3 : 1 and SiO_2 and B_2O_3 in the ratio 2 : 1 lowers the melting temperature by 15 – 20% and the firing temperature by 20 – 30°C without adding new components into the enamel composition. On the basis of the results obtained in this work, the enamel compositions Nos. 3 and 6 can be recommended for further commercial tests.

REFERENCES

1. A. Petzold and H. Peshmann, *Enamel and Enamelling* [Russian translation], Metallurgiya, Moscow (1990).